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M3Or4B-04 [Invited]: Cryogenic Integrated Circuits for Quantum Computing

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Superconducting quantum processors are controlled and measured in the analog domain and the design of the associated classical-to-quantum interface is critical in optimizing the overall performance of the quantum computer. Control of the processor is achieved using a combination of carefully shaped microwave pulses and high-precision time varying flux biases. Measurement of quantum states is typically achieved using dispersive readout, which requires a low-power pulsed microwave drive and a near quantum-limited readout chain. For control of a single qubit, a typical system employs two high-speed high-resolution (e.g., 1 Gsps/14 bit) digital-to-analog converters (DACs) and a single-sideband modulator to generate microwave control pulses. A third DAC with similar specifications is used for flux-bias control. A typical readout channel may service on the order of five qubits and contains yet another pair of DACs, with a single-sideband modulator employed to generate a stimulus signal. For measurement, the readout chain also employs a series of cryogenic amplifiers followed by further amplification, IQ demodulation, and high-speed digitization at room temperature. For today's prototype systems with on the order of 50-100 qubits, keeping most of the electronics at room temperature makes sense. However, achieving fault tolerance—a long term goal of the community—will require implementing systems with on the order of $1e6$ qubits and today's brute force control and readout approach will not scale to these levels. Instead, a more integrated approach will be required.

In this talk, we will present a review of recent work towards implementing a scalable cryogenic quantum control and readout system using silicon integrated circuit technology. After motivating the work, we will describe key challenges in implementing such a system. Two examples of cryogenic integrated circuits will be presented: ultra-low-power LNAs for qubit readout and low-power CMOS pulse modulators for quantum control. The talk will conclude with a discussion of future work.

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